NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

CONCEPTS AND METHODS OF MEASURING PRODUCTIVITY AT THE ORGANIZATION LEVEL

by

Maxie Y. Davis

September, 1993

Co-Advisor: William J. Haga
Co-Advisor: William R. Gates

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE SEPT93	3. REPORT TYPE AND DATES COVERED Master's Thesis 19SEPT91-23SEPT93

4. TITLE AND SUBTITLE CONCEPTS AND METHODS OF MEASURING PRODUCTIVITY AT THE ORGANIZATION LEVEL	5. FUNDING NUMBERS
6. AUTHOR(S) Maxie Yvonne Davis	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	12b. DISTRIBUTION CODE

13.

ABSTRACT *(maximum 200 words)*

This thesis addresses the concepts of productivity measurement. Productivity measurements are generally expressed as a ratio between outputs and inputs. The criteria for identifying and quantifying the output and input components are explored.

The methodology used by the Bureau of Labor and Statistics are examined to provide insight into the application of the concepts of productivity measurement. Business and government sectors outputs are identified and partial and multifactor productivity measurements defined.

Common methodologies for measuring productivity at the organization level are also outlined. These methodologies are examined for their applicability to phenomena of the post-industrial society, particularly the rise in the white collar work force, information technology and process reengineering. Adaptations of these methodologies are proposed an as appropriate measurement technique for DOD functional managers.

14. SUBJECT TERMS output/input, partial and multifactor productivity, white collar productivity, information technology, process reengineering	15. NUMBER OF PAGES 67
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)

Prescribed by ANSI Std. 239-18

Approved for public release; distribution is unlimited.

CONCEPTS AND METHODS OF MEASURING PRODUCTIVITY AT THE ORGANIZATION LEVEL

by

Maxie Y. Davis
Lieutenant, United States Navy
B.S., Tuskegee Institute, 1980

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN INFORMATION TECHNOLOGY MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
September 1993

Author: Maxie Y. Davis
Maxie Y. Davis

Approved by: William J. Haga
William J. Haga, Co-Advisor

William R. Gates
William R. Gates, Co-Advisor

David R. Whipple, Chairman
Department of Administrative Sciences

ABSTRACT

This thesis addresses the concepts of productivity measurement. Productivity measurements are generally expressed as a ratio between outputs and inputs. The criteria for identifying and quantifying the output and input components are explored.

The methodology used by the Bureau of Labor and Statistics are examined to provide insight into the application of the concepts of productivity measurement. Business and government sectors outputs are identified and partial and multifactor productivity measurements defined.

Common methodologies for measuring productivity at the organization level are also outlined. These methodologies are examined for their applicability to phenomena of the post-industrial society, particularly the rise in the white collar work force, information technology and process reengineering. Adaptations of these methodologies are proposed as an appropriate measurement technique for Department of Defense (DOD) functional managers.

TABLE OF CONTENTS

I. INTRODUCTION

Measuring productivity is a complex matter. The concepts and measures of productivity are various, broad and elusive. The terminology associated with productivity measurement is often misinterpreted. The inconsistencies and availability of data obscure the measurement as well. The validity of the measure--the relationship between the data collected and the phenomena observed--can be a source of much skepticism. The desired degree of reliability or accuracy is often unattainable. Nonetheless, the undertaking of measuring productivity can provide insight about a work process under observation.

A. BACKGROUND

The current doctrine of the Office of the Director of Defense Information dictates process reengineering as a prerequisite to automation. This doctrine is driven by the need for improvements in quality and increases in productivity. Productivity measures are tools needed by the Department of Defense (DOD) functional managers in making decisions about information technology investment and business activity reengineering. Current DOD measurement and calculation procedures used DOD may not meet these

intended purposes. The extrapolation and rule-of-thumb techniques used by many organizations are not suitable for making decisions about investments in information technology and about process reengineering. Organization level productivity must be more than a rough guide. It must provide dependable data to support information technology investment and re-engineering decisions.

B. OBJECTIVE

The focus of this research is to examine the theoretical work on measuring productivity at the organization level; report the techniques commonly used; and recommend measurement techniques most accessible to Department of Defense (DOD) functional managers.

C. LITERATURE REVIEW AND METHODOLOGY

This effort is based on the result of previous research by the Bureau of Labor and Statistics, professional papers from the First International Productivity Symposium, the American Productivity Center and academic literature. The Bureau of Labor and Statistics has invested heavily in refining productivity measurements and is a common source of information for organizations developing productivity measures. The American Productivity Center has a library of productivity measurement material and has acted as a consultant on productivity measurement. The U.S. Navy is a

member of the Center. The focus of the First International Productivity Symposium was on measuring productivity.

The methodology employed in this thesis is as follows:

* Review references for the general concepts and principle of productivity measurements;
* Review and analyze theoretical work for measuring productivity at the organization level;
* Examine case studies of productivity at the organization level;
* Extract commonalities and variations from case studies;
* Draw conclusions.

II. BACKGROUND

A. PRODUCTIVITY MEASUREMENT: RATIOS AND INDEXES

Measuring productivity, in a broad sense, addresses the relationship between the inputs needed to begin a production process and the end outputs of that process. This relationship is commonly expressed as a ratio of an output divided by the input as illustrated in Figure 1.

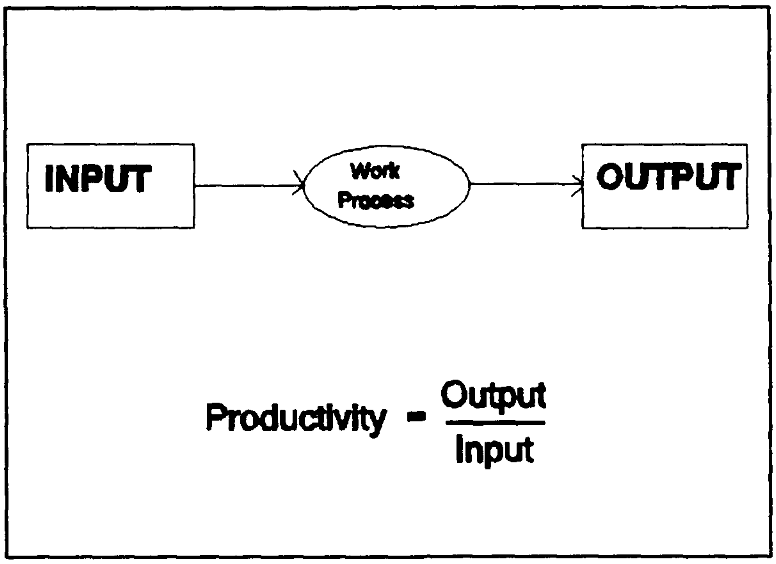

Figure 1: Productivity Ratio

Productivity measurement, in an economic sense, is the ratio of physical or real volume of goods and services to related physical or real quantities of inputs. Physical output and input are strictly quantitative measures, usually refer to

tangible units, and exclude all dimensions that represent value or quality of the input or output. Real can mean the total volume of goods and services produced or used in production, free of the price changes that affect money values. Regardless of whether outputs and inputs are termed as real or physical: "This measure cannot be free of all criteria of relative value...we need a measure of relative value in order to combine, into meaningful total, the heterogenous goods and services that make up output and input." (Fabricant, 1984) Of equal significance, relative value is necessary for a meaningful comparison and analysis of the output to input ratio.

1. Output

The output represents the result of an activity; work done, goods produced, services provided, etc. Brinkerhoff and Dressler (1990) define the concept of output in productivity measurement as follows:

* An output is expressed as some unit of quantity (number, amount, gallons, and so forth);
* Outputs may have a qualitative expression attached to them, such as "units meeting quality specification" or "gallons with no impurities or residues;"
* Outputs represent desired results and are not always tangible goods; and
* Output identification, in productivity assessment, requires and assumes measurability. Clear-cut rules and procedures for identifying outputs must exist.

Throughput is an output of one step of production that becomes an input in another stage of production. It is an intermediate good, one that will eventually be consumed in subsequent steps of production. Throughput identification and measurement can provide information needed for productivity measurement.

2. Input

Input represents those resources consumed in the production of outputs. Inputs can include all tangible and intangible resources, the services that support production, and the efforts of people to produce the output. Usually the focus in productivity measurement is on one, or a few major inputs. The concept of input mirrors that of outputs with the obvious exception: inputs must represent the actual expenditure of resources.

3. Indexes

Productivity indexes are based on comparing the present productivity ratio with the ratio of a previous period referred to as the base period. Established standards can also provide the basis for comparison. In either case, the direction and the magnitude of change in productivity can be expressed using indexes.

An index number, which is simply the percentage change added or subtracted from 100, offers several advantages. Indexes are easily converted to other indexes;

ideal for charting trends lines; and can be compared with other productivity indexes, specifically those produced by the Bureau of Labor Statistics. (Bain, 1982)

B. OBJECTIVES OF PRODUCTIVITY MEASUREMENT

At the national level, "the perennial interest in productivity and productivity measurement and analysis originates mainly in two concerns...economic efficiency and economic welfare." (Fabricant, 1984) At the organizational level, efforts to measure productivity are driven by a central purpose--control and feedback. This purpose is motivated by the paradigm, "You can't manage it if you can't measure it". (Jones, 1993)

The data from productivity measures have been included in several applications. Some of the common applications are (Brinkerhoff and Dressler, 1990):

* A relative indicator of efficiency.
* Determining overall performance.
* Forecasting and analysis of costs, prices, wages, and technological change.
* Long term trend analysis.
* Indicator of success or failure.
* Comparing individuals, units, organizations and competitors.

C. GENERAL APPROACHES TO PRODUCTIVITY MEASUREMENT

1. Basic Categories Of Measurement

The two broad categories of productivity measurement are partial and multifactor. Partial productivity measures relate a single or aggregate output to one type of input. Multifactor productivity measures relate a single or aggregace output to a combination of inputs.

a. Partial Productivity Measurement

Measures that relate output to a single input do not measure the specific contribution of that input to the output. Instead, these measures express the composite effect of a number of interrelated influences on the use of that input in the production process. These interrelated influences can be changes in technology; layout and flow of materials; managerial skills; level of output; the organization of production; capital investment; the skill level and effort of the work force; and the utilization of capacity and energy. (U.S. Department of Labor, 1983)

The most common partial productivity measurement is an output per unit of labor input measure. This measurement is prominent because the labor factor and its associated costs, is required in all production in some form or another; and the data are readily available. Labor input is usually expressed in man-hours. Time is a good common denominator since it is universal.

b. *Multifactor Productivity Measurement*

This measure is useful when the concern is overall efficiency. Generally, the broader the coverage of resources, the better the efficiency measure. The effects of substitution, which is directly linked to efficiency, is incorporated in productivity measures of this type. Although there are few perfect substitutes, there are substitutes and this can not be ignored in any measure that addresses the use of resources. (Fabricant, 1984)

Multifactor productivity is often mistaken as total factor or simply total productivity. Total implies complete coverage of all inputs. "The measures of total factor productivity that private economists have concocted relate output not to total input...not all the input factors are covered; and the factors that are covered are not always fully covered." (Fabricant, 1984) When this is true, the less inclusive term multifactor productivity is more appropriate.

Based on a linear relationship between inputs and outputs, multifactor productivity measures are basically an arithmetic average of several partial (single input) productivity measures. Each partial productivity is weighted by its relative importance; usually, but not necessarily, its percentage of the cost of the total inputs.

As illustrated below:

$$P_{1,2,3} = \frac{OUTPUT}{aINPUT_1 + bINPUT_2 + cINPUT_3}$$

Where partial productivity for $INPUT_1$, $INPUT_2$, $INPUT_3$ are:

$$P_1 = \frac{OUTPUT}{INPUT_1}$$

$$P_2 = \frac{OUTPUT}{INPUT_2}$$

$$P_3 = \frac{OUTPUT}{INPUT_3}$$

and a, b, c, are respective weights of the inputs.

A linear view of the process asserts that partial productivity measures are constant. Changes in outputs are directly proportional to changes in inputs. However, Yan (1969) states "economic theory postulates that the productivity of labor decreases as the amount of labor input alone increases and it increases as the amount of capital increases." These and other possible interrelations among inputs are neglected in this approach to multifactor productivity. This has lead to the use of econometrics in measuring multifactor productivity.

Econometric methods of determining multifactor productivity are based on a relationship that is linear in the logarithms of the inputs and outputs. The log-linear relationship captures the interrelations among inputs. Changes in outputs may not be directly proportional to

changes in inputs. Any change in output left unexplained by the interrelationship of inputs are considered productivity growth. (Christ et al., 1969) Although statistical evidence suggests an indirect change in outputs to inputs in many cases, the assumption of a direct relationship is probably "... not too much out of line with the available facts." (Yan, 1969)

2. General Techniques

Productivity can be measured by three general techniques: quantitative, semi-quantitative and qualitative. Quantitative techniques usually follow a specific algorithm or predefined ratio to generate numbers that can be compared with other measures and past experience. Semi-quantitative techniques are basically qualitative judgments that are converted to numbers. Qualitative techniques involve intuitive judgments based on past experience with a task.

III. PRODUCTIVITY MEASUREMENT AT THE NATIONAL LEVEL

As a benchmark for evaluating productivity measurement at the organization level, it is helpful to grasp the means by which productivity is measured at the level of a national economy. The official source of statistics for productivity within the United States is the Bureau of Labor And Statistics (BLS) of the Department of Labor. This agency is the primary authority and a source of reference for organizations measuring productivity. This discussion of productivity at the national level is a broad one, only intended to introduce the methods described in the BLS Handbook of Methods (1992).

A. BUSINESS SECTOR AND MAJOR SUBSECTORS

The BLS publishes various sets of productivity indexes for the business sector and its major subsectors at various time intervals. These set of indexes are categorized by the coverage of inputs: labor productivity; multifactor productivity; and intermediate purchase multifactor productivity. TABLE 1 summarizes the availability of productivity measures for the major sectors of the U.S. economy.

TABLE 1: U.S. Productivity Measures
(U.S. Department of Labor, 1992)

Productivity Measure	Input	Index Available
Labor Productivity:		
Business	Labor	Quarterly
Nonfarm business	Labor	Quarterly
Nonfinancial corporations	Labor	Quarterly
Manufacturing, total	Labor	Quarterly
Durable	Labor	Quarterly
Nondurable	Labor	Quarterly
		Quarterly
Multifactor Productivity:		
Private business	Labor, Capital	Annually
Private nonfarm business	Labor, Capital	Annually
Manufacturing, total	Labor, Capital	Annually
Intermediate Multifactor Productivity:		
Manufacturing industries	Labor, Capital Energy, Materials, Services	Annually

1. Output Component

a. Labor and Multifactor

The business sector output components for labor and multifactor productivity indexes are based on the National Income and Products Accounts (NIPA), including the Gross Domestic Product (GDP) measures prepared by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce. Business sector output, measured as real gross

product originating (GPO), is defined as the gross domestic product (GDP) in constant base year dollars less general government, output of nonprofit institutions, output of paid employees of private households, rental value of owner-occupied dwellings and the statistical discrepancy in computing the NIPA. The business sector excludes many activities where it is difficult to draw inferences on productivity from the NIPA output measures. (U.S. Department of Labor, 1992)

The output of the major subsectors--nonfarm business, nonfinancial corporations, total manufacturing, durable manufacturing and nondurable manufacturing--are defined as:

* Nonfarm business output is equal to the business sector output minus farming. The farm sector, which is subject to unique external forces, is subtracted to yield the nonfarm business sector, the principle focus of many productivity studies;

* Nonfinancial corporation output is equal to nonfarm business sector output less unincorporated business, the output of corporations engaged in banking, finance, stock and commodity trading, and credit and insurance agencies; and

* Total manufacturing measures are computing by summing the durable and nondurable goods sectors. Durable goods include the following broad categories of industries: primary metals; fabricated metal products; industrial machinery and equipment; electronic and other electric equipment; transportation equipment; instruments; lumber and lumber products; furniture and fixtures; stone, clay and glass products; and miscellaneous manufactures. Nondurables include: textile mill products, apparel products, paper and allied products, leather products, printing and

publishing; chemical products; petroleum products, rubber and plastic products; food and tobacco products.

b. Intermediate Purchase Multifactor

The output component of the intermediate purchase multifactor productivity indexes are also based on the GPO but are farther defined as the real value of production minus the change in real inventories.

2. Labor Input

The labor input of business and major subsectors is defined hours at work. The measure of hours at work refers to time actually spent on the job, as well as rest periods, paid time to travel between job sites, coffee breaks, machine downtime, standby or ready time, paid training periods, paid preparatory time, etc. Hours at work can be determined by subtracting hours of paid leave (sick, vacation, holiday, personal or administrative) from total hours paid. Hours of labor input are treated as homogeneous units with no distinction between skill levels or wages.

In 1989, the BLS began using hours at work in its productivity and cost measures after conducting the Hours at Work Survey. The Hours at Work Survey, which yields ratios of hours at work to hours paid, is used to convert the hours paid to hours-at-work. "This survey ... revealed that if the rates of growth in hours paid and hours at work diverged, an incorrect productivity growth would result if

hours paid rather than hours work was used in the measurement." (Jablonski et al, 1990) The estimates of hours of farm workers, proprietors, unpaid family workers, employees of government enterprises, and paid employees of private households are on an hours-at-work basis and no adjustment is required.

The primary source of hours and employment data is the BLS Current Employment Statistics (CES) program. It provides monthly data on total employment and average weekly hours of production and nonsupervisory workers in nonagricultural establishments. The average weekly hours for production workers is taken directly from the CES data. Average weekly hours for nonproduction workers is developed from BLS studies of wages and supplements. It provide data on the regularly scheduled work week of white collar employees.

The CES data are based on payroll records collected monthly; the reference period for these data is the payroll period including the 12th of the month. Along with hours paid, jobs rather than people are counted, so that multiple jobholders are counted more than once. Separate estimates for employment and hours paid are developed for each major subsector and are aggregated to business and nonfarm business levels.

Because CES data include only nonfarm wage and

salary workers, data from the Current Population Survey (CPS) and NIPA are used for farming, nonmanufacturing, government enterprises, proprietors, unpaid family workers and paid employees of private households subsectors.

Employment, hours-at-work, and compensation to employees enter into the productivity equation. Indexes of compensation per hour measure the employers' hourly cost of wages, salaries, and supplemental payments. Supplemental payments include employer's contributions to Social Security, unemployment insurance taxes, private health insurance and pension plans. Measures of real compensation per hour adjust hourly compensation for changes in the Consumer Price Index for All Urban Consumers (CPI-U).

3. Multifactor Input

Multifactor productivity indexes are prepared for private business, private nonfarm business and the corresponding manufacturing subsector. The private business sector excludes government enterprises.

Multifactor inputs are an aggregate measure of hours-at-work and service capital flows. "These measures has been developed in the recognition of the role capital growth plays in output growth." (U.S. Department of Labor, 1992)

Capital inputs for the multifactor productivity measures are computed in accordance with a service flow concept (as distinct from a price or value concept) for

physical capital assets--equipment, structures, inventories and land. Capital inputs for major sectors are determined in the following steps: (1) Capital stocks are developed for various assets types in various industries; (2) These asset type capital stocks are aggregated for each industry to measure capital input for the industry; and (3) These industry capital inputs are aggregated to measure the sector level capital input.

BLS measures of capital stocks for equipment and structures are prepared using NIPA data on real gross investment. Inventory stocks are also developed using data from the NIPA. Farm land input is based on data from the Economic Research Service of the U.S. Department of Agriculture. A benchmark for nonfarm land is estimated by applying a land-structure ratio based on estimates by the U. S. Bureau of Census to BLS estimates of the value of structures. This benchmark is extrapolated using gross stocks of structures calculated from U. S. Bureau of Economic Analysis investment data. The resulting nonfarm land data series is allocated to industries based on Internal Revenue Service data on book values of land. (U.S. Department of Labor, 1992)

For each industry in the private business sector, the capital stocks are aggregated using a Tornqvist chain index procedure. The Tornqvist formula yields growth rates

which are differences in logarithms. The antilogs of these rates are chained together to form the index. Weights for the capital stocks are based on the share of property income accrued to that capital stock (using the implicit rental price concept).

The sector capital input is subsequently measured as the Tornqvist chain index of the capital inputs for each industry within that sector. Weights of the capital input for each industry are determined by the industry's share of the total nonlabor payments in the sector.

The capital input of the sector is combined with the labor input of the sector using, again, the Tornqvist procedure. These inputs are weighted by the share of total costs derived from NIPA data on the components of nominal GPO by industry.

4. Intermediate Purchase Multifactor Input

An intermediate purchase multifactor productivity measurement is prepared for 20 manufacturing industries. This multifactor productivity is termed KLEMS multifactor productivity. The acronym is an abbreviation for capital (K), labor (L), energy (E), materials (M), and purchased business services (S) inputs. KLEMS represents a weighted aggregate of these inputs.

Capital and labor are measured as per multifactor productivity described in the last section. Energy input is

constructed using data on the price and quantity of fuels purchased for use as heat and power. Nonenergy material inputs include all commodity inputs exclusive of fuels but inclusive of fuel-type inputs used as raw materials in manufacturing. The measures of purchased business services are constructed using price and value data on services purchased by manufacturing industries from service industries. Data sources used in constructing these three inputs include input-output tables, surveys and price indexes.

Total input is computed from the components as a Tornqvist chain index number series. The weight for each input is its share in total input cost.

B. INDUSTRIES AND GOVERNMENT

A separate set of productivity measurements is prepared by the BLS for approximately 170 industries, 23 selected government functions, the Federal Government as a whole, and selected service areas of State and local government. These measurements include labor, multifactor and KLEMS multifactor measurements.

1. Industries

The industry studies cover a variety of manufacturing and nonmanufacturing industries. Some of the nonmanufacturing industries include mining, trade,

transportation, communication, public utilities, finance, and business and personal services sectors.

The index construction follows the same methodology as the business sector measurement in determining labor and multifactor productivity. However, the definition and the source of data for the output measure differs. The industry output measurements are based on physical or deflated value of industry production combined with fixed-period weights. Physical quantities are used when available. If not, constant dollar value of shipment sales or revenue data are used to define output. Output data is extracted from economic censuses, mainly the Census of Manufacturing.

2. Government

Labor productivity indexes are constructed for 304 organizations and 28 functional areas of the Government; covering about 64% of the Executive Branch. The 28 functional areas reflect common activities found in most government agencies. These functions along with sample outputs are outlined in Appendix A.

Productivity measures for the Federal Government in the Federal Productivity Measurement System (FPMS) compare the current year input-output relationship with that of a base year reference period. These measures reflect the changes which have actually taken place regardless of the

mission. (U.S. Department of Labor, 1992)

Government productivity data are collected annually in response to a request by the Commissioner of Labor Statistics. The request asks for output and input data. The Commissioner also requests descriptions of the output measures and some explanations of the output and input trends. Although most of the data are provided directly to the Bureau, some measures are developed from agency budget reports and congressional hearings. The data are processed and analyzed by the Bureau before returning the completed productivity results to the agencies. Productivity measures are provided to the agencies on an activity level, by organization and in a combined agency summary. The organizations are also regrouped into 28 functions for publication purposes. This enables organizations to compare themselves to other groups performing similar functions. (Forte, 1992)

a. *Output*

"The development of the output measures is the most challenging part of the measurement process." (Forte, 1992) Like private industry, government agencies produce goods and services for outside consumption. Unlike private industry, government services are not sold on the open market. Therefore, they are not subject to a direct market valuation. In addition, many Federal activities are

service-oriented. This makes defining and quantifying outputs problematic. Special attention and assistance from the BLS is required in developing output indicators.

The primary requirement for outputs is to define the products or services which are measurable over a period of time on a consistent basis. The framework developed for defining and quantifying outputs includes several important criteria: the agencies must identify specific units of services or products which are countable; they must be final, not intermediate outputs; they must be fairly homogenous over time; and they must reflect a significant proportion of the agencies' workload. Since this is a voluntary program, the data is usually derived from readily available records.

Special effort is taken to separate outputs that are known to have significantly different labor times to produce. Outputs are reported in sufficient detail so that those activities requiring greater labor time to produce are grouped separately from those that are less labor intensive. If the outputs do not have similar labor requirements and there are shifts in the product mix, the resulting productivity indexes would be misleading.

Since a typical organization produces five or six outputs, the various outputs must be combined with appropriate weights. In the FPMS base year, labor weights

are used. Most output weights are developed from the actual output and employee year data submitted to the Bureau. The weight is equal to employee years divided by the output in the base year. This employee year weight is used for the output it represents for an entire five year period.

Since one federal agency may consume all or some of the outputs of another federal agency, all output indicators are not final from the perspective of the entire federal government. Therefore, the overall statistics presented in the study do not represent federal government productivity, but rather the average of the productivity changes of the measured federal organizations included in the sample. (U.S. Department of Labor, 1992)

b. Input

The input side of productivity measurement focus only on labor; specifically, employee years. One employee year is defined as 2,087 hours. Employee years are treated as homogenous and additive. All Federal Government agencies count employee years, more commonly called FTE's (full time equivalents), as part of the budget process. Many agencies report the FTE's associated with each program or output. Thus, productivity measures, can be developed on an output level as well as by organization. All labor hours associated with the output, including those devoted to intermediate tasks, are included as part of the input.

Since Federal employment has been fairly constant, productivity increases primarily reflect output growth. (Forte, 1992)

C. USES AND LIMITATIONS AT THE ORGANIZATION LEVEL

The BLS methods of productivity measurement provide conceptual and mathematical insight into measuring productivity at the organization level. The hours at work definition, the service flow concept of capital and the inclusion of intermediate inputs can be incorporated into organization level measures. The framework for defining and quantifying outputs at the federal government level serves as a guide for DOD organizations. The BLS Handbook of Methods (1992) also describes several useful calculation procedures. These include formulas for unit labor and nonlabor costs, seasonal adjustments, weighting, growth rate of index, labor and capital share, and current year to base year conversions. Application of the Tornqvist formula, used in multifactor calculations, is also included.

The BLS expertise is aggregation of data supplied by several organizations. This limits the use of BLS methodology at the organization level in the following ways (U.S. Department of Labor):

* Existing techniques may not fully take into account changes in the quality of goods and services.

* Changes in the degree of integration and specialization are often not reflected adequately in the statistics.

* Shifts in the workforce or product mix are not highlighted.

* Extrapolation techniques used to estimate of outputs in the service sector are based on the assumption that productivity is constant. Actual changes in output may not be reflected.

IV. PRODUCTIVITY MEASUREMENT AT THE FIRM LEVEL

The concepts and calculation techniques employed by the BLS can be adopted at the organization level. However, the broad perspective of productivity measurements based on total output measures such as the GDP, or the total goods and services produced by the economy have little or no real value to a single organization. (Bain,1982) Measurements are required that relate and are useful to an individual organization. This chapter summarizes the primary productivity measurements at the organization level.

A. LEVELS OF MEASUREMENT

Productivity can be measured at three levels of the organization; individual, department and the organization as a whole. The nature of the business and the availability of data greatly influence the level to be measured. Once the measurement level has been determined, it is common practice to make inferences about other levels, through extrapolation and rules of thumb. (Bain, 1982)

B. DEGREE OF REDUCTION

"The science of measurement requires that large complex phenomena be 'reduced' to objective, operational, and measurable dimensions that will submit to quantitative

expression." (Brinkerhoff and Dressler, 1990) In measuring productivity at the organization level, the degree of reduction falls into two categories: single or family measures. Single measures reduce the entire concept of productivity to a single number. Family measures are a group of related discrete productivity indicators.

Many organizations are too complex and interdependent to allow simple factor quantification. The family measure approach recognizes as many aspects of the work as possible. A single indicator can then be mathematically formulated by assigning weights to the members of the family.

C. SCOPE OF THE MEASURE

As mentioned earlier, there are total measures and partial measures. The use of partial measures at the organizational level is more prevalent than total measures. Partial measures are easier to develop and supported by definitive theoretical work, specifically in labor productivity.

Along with labor, organizations are also defining partial productivity measures for capital, material and energy productivity. Examples include:

Labor Productivity = output per manhour
= output per employee
= output per labor cost

Capital Productivity = output per dollar invested
= output per dollar consumed
= output per machine hour

Material Productivity = output per unit consumed
= output per dollar value
= output per constant dollar value

Energy Productivity = output per unit of energy
= output per dollar energy cost
= output per constant cost

Partial measures are powerful tools when directed at specific problems but they are often misleading when used to assess overall efficiency. Organizations focus on partial measures when addressing a specific problem and total measures to highlight overall efficiency. (Adler, 1987)

Total firm productivity measures the relationship of weighted inputs of labor, capital, materials and energy against an output. All resources of an organization can be represented in these four categories. For this reason, total firm productivity measures are useful but complex. "Total firm productivity measurements in the past have been too sophisticated and therefore vulnerable to subversion by threatened managers; too simple and therefore unreliable in the presence of such common but analytical complex phenomena such as product mix." (Adler, 1987)

D. COMMON METHODOLOGIES

Reviewing case studies and guides for measuring productivity at the organization level indicates that organizations typically use a variation of two methodologies: the traditional input-output model and the productivity measurement objective approach.

1. Input-Output Model

The input-output model implies the simple conceptual model of production as shown in Figure 1. The methodology based on this model fundamentally follows these steps:

Step 1: State the key purpose of the units under observation. For example, a data processing unit's purpose is to collect information and compile into reports;

Step 2: Identify physical outputs that accounts for the majority of the unit's expenditures. The physical outputs that account for the majority of the data processing unit is reports;

Step 3: Identify and describe the major functions of the unit. The major functions of the data processing unit is data collection, sorting, storage, formatting and report generation;

Step 4: Construct measurement criteria for key outputs. The number of timely, accurate reports is the output measure for the data processing unit;

Step 5: Construct measures for key inputs that are critical to the production of the outputs. The computer and labor costs of generating reports represent the key inputs of the data processing unit. Computer and labor costs can be collected by functions identified in Step 4; and

Step 6: Construct a productivity index that incorporates the output and input measures. Assuming the

data processing is computer intensive, the weight for computer cost is assigned a 80% weight and the labor cost a 20%, the resulting productivity index is:

$$\frac{\text{number of timely, accurate reports}}{0.80(\text{computer costs}) + .20(\text{labor costs})}$$

A variation of this model has been proposed as a framework for incorporating professional, administrative and service organizations. In these organizations, the most measurable or countable outputs are often not those that best measure successful achievement. Quality is often more important quantity. Thus the customer is included in the model, as shown in Figure 2. Data from the customer can be obtained through questionnaires, surveys, repeat business in competitive markets and etc. (Christopher, 1983)

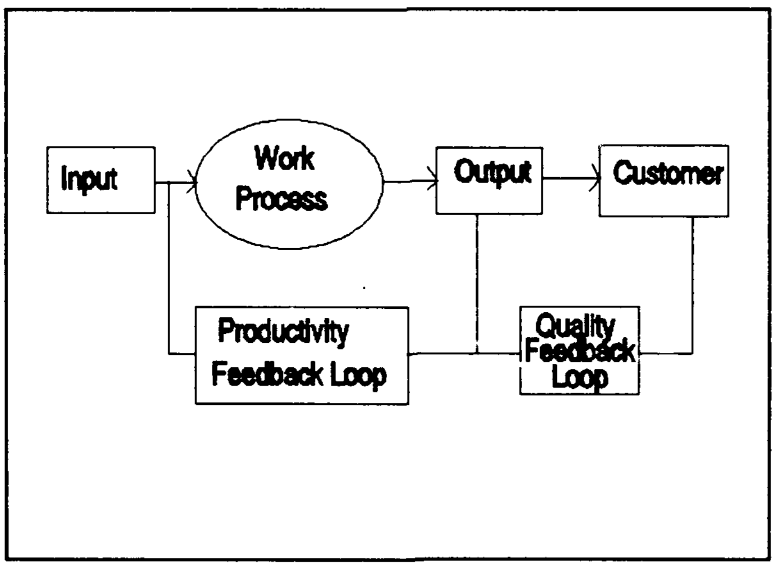

Figure 2: Productivity and Quality (Christopher, 1983)

The first two steps of the methodology are modified to accommodate this model:

Step 1: State the key purpose and customers of the unit. For example, a data processing unit's purpose is to collect information and compile into reports for use by managers within the organization; and

Step 2: Identify outputs that are important to the unit's mission, responsive to customer needs and expectations, and account for the majority of the unit's expenditures. The number of timely, accurate summary reports that support the manager's decision making process is an output measure for the data processing unit.

The input-output methodology, based on the BLS methodology, is supported by a significant amount of theoretical work and ideal for productivity assessment when inputs and outputs are tangible, easily identifiable and quantifiable.

2. Measurement By Objective

This approach to measuring productivity compares achievements to objectives. "The traditional approach of ratios, indexes, percentages...can be a dubious, complex and frustrating undertaking." (Felix and Riggs, 1983) Measurement by objective approach tries to overcome the complexity problem and provide a more comprehensive picture of productivity. This method focuses directly on results and can be used by manufacturing, governmental, service and administrative support type organizations (Felix and Riggs, 1983).

In this methodology, an objectives matrix is constructed by combining all of an operation's important productivity criteria into one interrelated format. This is accomplished by relating various performance levels to scores from zero to ten. The scores, zero to ten, serve to normalize the measures used in the matrix by establishing a uniform quantitative rating system. A sample matrix is illustrated in Figure 3 (Felix and Riggs, 1983). The matrix is constructed in seven steps:

Step 1: Identify the key productivity indicators. For each criterion form a ratio and ascertain the availability of data;

Step 2: Assess current level of performance for each criterion and assign a value corresponding to a score of three to allow for greater room for improvement than for declines. The current level of performance for late orders per total orders is five percent. The five percent corresponds to the normalized performance score of three;

Step 3: Assign target performance value at a level corresponding to a score of ten. The target value, or goal, for the late orders per total orders is zero percent and corresponds to the normalized score of ten;

Step 4: Define step-wise goals. Fill in the normalized scores between three and ten with these stepwise goals. A four percent late orders per total orders which corresponds to a normalized level of four is better than the current performance but is merely a step toward the target value;

Step 5: To account for tradeoffs or occasional slack periods, assign values to levels below three. An organization may operate below its current performance level of late orders per total orders because of increased machine downtime;

Step 6: Assign importance by weighing the criteria. The sum of these weights equals 100, and can be distributed according to its contribution to accomplishing the mission of the organization. Units per labor hours carries a weight of 30 percent. This measure represents the most important relationship in this organization; and

Step 7: At the conclusion of each monitoring period, actual performance of each criterion is determined and placed in the performance boxes, row A, on the matrix. For the units per labor hour, this value is 605. The level that this achievement represents is then circled in the body of the matrix and associated with its corresponding score of 0 to 10. For the units per labor hour, 590 is circled and the corresponding normalized value of three is entered into row B. Each score is multiplied by its weight, row C, and the sum of all values yields a productivity index for the period. Over time, the movement of this single index tracks the changes in productivity.

The objective matrix methodology builds on the input-output methodology, in that efficiency measures can be examined simultaneously with effectiveness measures and inferential measures. Inferential measures are those measures that indirectly impact on productivity. These include safety, attendance, employee turnover and etc.

Step 1	Late Orders / Total Orders	Down Time / Scheduled	#'s Out / #'s Recv'd	Units / Labor Hrs	5 * (Safety) + Severity	Defects / Total	Productivity Criteria	
Row A	5.5%	16%	13.25%	605	320	9.5%	Performance	
Step 3	0	0	10	800	0	0	10	
	.2	2	11	770	50	3	9	
	.5	4	12	740	125	5	8	
	1	6	13	710	175	7	7	
	2	8	14	680	225	9	6	
	3	10	15	650	275	11	5	Scores Step 4
	4	12	16	620	325	13	4	
Step 2	5	14	17	590	375	15	3	
	6	16	18	560	390	17	2	
	7	18	19	530	405	19	1	
Step 5	8	20	20	500	420	21	0	
Row B	2	2	6	3	4	5	Score	
Step 6	5	10	20	30	15	20	Weight	
Row C	10	20	120	90	60	100	Value	

Step 7: INDEX = 400

Figure 3: Objective Matrix (Felix and Riggs, 1983)

E. DATA SOURCES AND CALCULATIONS

1. Traditional

Aside from rare instances of direct observation and record keeping aimed at measuring productivity, the data for productivity measures are usually derived from an organization's records, generally cost accounting records. As a result, calculations are driven by the way the data are represented in a cost accounting system. A cost accounting system does not completely support this type of measurement and analysis, but it is the richest source of data relating output to input for most organizations (Miller, 1988).

Labor input data are usually extracted from payroll and cost accounting records. The primary unit of labor input is man-hours worked. Total man-hours by all hourly wage employees is converted to dollars by multiplying the man hours by an appropriate hourly wage rate in base years. Vacation pay and fringe benefits costs are usually included. A head count of all salaried employees is multiplied by an average annual base salary.

Capital input is probably the most difficult to define. Cash, accounts receivable, securities, inventory, and other liquid assets are parts of the capital input factor. Most previous work in productivity measurements has recommended that capital input be considered as the physical use of the equipment. Depreciation and other

capital consumption obtained from accounting records are generally used as the approximation of the capital consumed in a production process. (Craig and Harris, 1973)

Capital input can also be defined as "the value of the services of capital...which includes more than capital consumption, and is not necessarily related to capital consumption in any close way..." (Fabricant, 1984) The validity of representing the actual consumption of an asset in a depreciation schedule is a controversial issue, primarily because depreciation expenses can never be identified uniquely for any given period. The service value of capital includes three factors: the cost of an asset, economic life and an investor's desired rate of return. An annuity schedule including these three factors is recommended to determine the annual capital input (Craig and Harris, 1973; Denison, 1989).

The intermediate purchase data for material input are extracted from inventory, warehouse, purchasing department and accounting records. Energy Input data are aggregates of utility bills and costs to generate energy.

The American Productivity Center has developed a measure that relates profitability, price recovery and productivity:

$$Profitability = \frac{Sales}{Cost}$$
$$= \frac{output\ quantity \times unit\ price}{input\ quantity \times unit\ cost}$$
$$= Productivity \times Price\ Recovery$$

Using this relationship, a productivity measure can be extracted from the ratio of total sales to total costs and the ratio of unit cost to unit price as illustrated below:

$$Productivity = \frac{\frac{sales}{costs}}{\frac{unit\ price}{unit\ cost}} = \frac{sales \times unit\ cost}{costs \times unit\ price}$$

This approach allows organizations to use the information gathered in determining the unit cost and setting unit price to gain information about productivity. (Ruch, 1981)

2. The New Math

Computer Aided Manufacturing-International (CAMI), a non-profit consortium, formed a coalition involving its members, professional accounting firms and government agencies to define the role of cost management in the

current environment of new manufacturing technologies. They concluded that a new math for productivity is needed; existing cost accounting systems do not adequately support the objectives of automated manufacturing. The fundamental difference between conventional cost accounting systems and the new math of productivity is one of focus. Activity accounting with an emphasis on direct traceability of costs was offered as a solution. (Miller, 1988)

Activity accounting focuses on financial and operational performance information about the significant activities of the business. A few activities constitute perhaps 80 percent of the total work within any organization. It is only necessary to track those few activities. Cost are accumulated along lines of activities.

The activity accounting system offers the following benefits:

* Improved visibility of cost drivers.
* Improved traceability.
* Exclusion of nonvalue-added cost that cost accountants usually include.
* Facilitates integration of cost accounting, performance measurement and investment management.

V. APPLICATION CONCERNS IN POST-INDUSTRIAL AGE

A. WHITE COLLAR PRODUCTIVITY

The white collar work force includes professional, technical, managerial, administrative, sales and clerical workers. The BLS estimates that white collar workers represent over 60% of the work force and expects this figure to continue to rise. The white collar force is more expensive than the blue collar work force, usually accounting for 70-80% of the total company payroll. For these reasons, measuring white collar productivity is an area of concern for many organization. (Thor, 1985)

Measuring white collar productivity is particularly challenging for the following reasons:

* Outputs are often intangible and nonrepetitive.
* Individual measurement is less valid because of interfunctional issues.
* Activities are not necessarily pre-optimized; cannot assume that the process is approximately correct.
* White collar professionals usually do not think of themselves as subjects of a study.
* Output may not be a final product but rather a building block to produce a final product or service.

Considering the difficulties of measuring white collar productivity, a quantifiable methodology may not be possible. In these cases, some organizations develop soft

numbers that alert managers to trends in productivity improvement or stagnation.

The objective matrix methodology, comparing achievements against objectives, has been applied to measuring white collar productivity. In applying an objective matrix methodology, employee involvement in determining the objectives and achievements has been stressed.

The APC uses a nominal group technique to construct the objective matrix for white collar workers. The nominal group technique involves forming an artificial group; a group that does not work together on a daily basis or report to a single manager. The nominal group contains a nucleus from a real group (the target group) and individuals from outside the group. The individuals outside the target group are representatives of the most important groups upstream or downstream from the target group. With the help of a facilitator, brainstorming measures of performance is undertaken by the nominal group. The eight best indicators are selected, measurability determined, an objective matrix formed and subjective scaling pattern created.

Anthony (1982) proposes the application of a disciplined input-output way of structuring white collar productivity measurement. "Although many people think professional activities are non-routine and non-repetitive, we have found if scale of reference is expanded they reoccur on a

predictable basis." (Anthony, 1982) It is possible to define measurable products for all white collar groups; all produce specific end products.

The Administrative Productivity Indicator (API) method approximates the techniques used in the traditional input-output model of plant productivity measurements. The API method includes quality feedback from the customer and participation of the white collar work force under observation in identifying the outputs. (Bolte, 1983-1984)

The input-output methodology can be reasonably applied to the clerical and administative fraction of the white collar work force. The objective matrix methodology can be applied to all divisions of the white collar work force. An efficiency measure may not represent the importance of the white collar work force. Effectiveness measures and inferential measures along with efficiency measure are better performance indicators of the white collar work force.

B. INFORMATION TECHNOLOGY

Information has now been added to the traditional lists of fundamental economic resources which are land, labor and capital. (Emery, 1987) The handling of information and information technology (IT) in the productivity equation is an area where definitive study is needed. "While more than

a dozen attempts have been made to build a theory, a good deal of work still needs to be done." (Panko, 1991)

The effects of information and information technology on productivity measures brings to focus many issues:

* How are the value and cost of information and information technology determined?

* Despite the efficiency improvements and cuts in labor costs, why are organizations not experiencing the expected big gains in productivity? (Business Week, 1988)

* If the biggest payoff in IT investments is in increased effectiveness; what role, if any, should productivity--an efficiency measure--play in IT investment decisions?

Borrowing from the management science discipline (Anderson et al., 1991) the value of information can be defined as the difference between the value of the output with the information and the value of the output without the information. If the value of the information is greater than the cost of the information, then an increase in productivity is possible. This approach is problematic in that some of the benefits of information technology are not directly related to the output and will be ignored under this scheme.

The expectations of productivity growth from information and IT investments raise other concerns about the quantification and analysis of productivity data. Many of the outputs are intangible and reported productivity gains are often misleading, especially with labor productivity.

In such contexts, increases in labor productivity will normally be the result, not the cause, of overall productivity improvement. There is often a tradeoff between labor and capital productivity. A total productivity measure, with the flexibility of extracting partial productivity data, could function equally well in labor-intensive environments and nonlabor intensive environments. (Adler, 1987)

The confusion with measuring productivity in automated and information-based processes is primarily attributed to efforts to integrate technology as a variable in the ratio between inputs and outputs. The use of the technology determines its place in the productivity equation.

When the technology is aimed at improving the product--the payoff is increased effectiveness--moving up on the cost curve. "No productivity increase appears in an industry when it improves its product without a corresponding increase or improvement in its inputs." (Denison, 1989) Outputs and inputs should reflect an increase, with an overall increase in productivity.

If the technology is aimed at maintaining the existing level of quality of the product and improving the process, the payoff is in increased efficiency--lowering the cost curve. (Emery, 1987) Lowering the cost curve is, in effect, an increase in productivity.

IT investment decisions based on cost reduction only may be counterproductive. The term, "the productivity paradox" is used to describe this dilemma. "Capital decisions are based on the classical return on investment calculations that seek to recover funds from saving and not from gains in business." (Business Week, 1988) Investment in IT can be based on the need to keep customers and gain new ones. This has a potential for increasing productivity by increasing the value and quality of the output.

Carlson and McNurlin (1992) suggest the following to deal with the dilemma of uncovering the payoffs of information technology:

* Distinguish between the different roles of information systems. Information systems can play different roles in an organization. They can increase organizational efficiency, carry out a business strategy and can be offered as a product or service. (Sprague and McNurlin, 1993) Measurement should be geared toward the role.

* Measure what is important to management. "Concentrating only on cost and monetary measurements may be short-sighted." (Sprague and McNurlin, 1993) Service and quality are becoming more important to managers and in many cases can only be assessed through nonmonetary measures.

* Use anchor measures. Anchor measures are operational indicators, that may or may not address costs. These measures depend on management objectives. Keen (1991) advocates that anchor measures demonstrate benefits that financial figures ignore.

* Assess investments across organizational levels. Curley and Henderson (1992) suggest that potential benefits of IT investments differ at various levels and thus a systematic way to separate these benefits is needed. Economic performance measures should be

evaluated at the individual, department and organization level.

These suggestions can be integrated into the objective matrix methodology. Matrices can include nonmonetary and anchor measures and can be be installed at any level of the organizations.

A proactive approach to IT investments is advocated by Panko (1991). Instead of focusing on measuring the impacts of IT on productivity, the focus should be on producing IT impacts deliberately. "The wrong questions have been asked...the right question is 'how do we produce the impacts we wish to have?'" (Panko, 1991) The objective matrix approach can be used to quantify the desire impacts or goals.

C. PROCESS REENGINEERING

Process improvement and automation of business processes are common methods aimed at enhancing productivity. But dramatic increases in productivity can be achieved when the power of modern information technology is used to redesign the business processes. (Hammer, 1990) Process reengineering offers the potential for decreasing the amount of inputs and increasing the value of the outputs by eliminating outdated processes. Hammer's (1990) article explains the essence and principles for process reengineering.

The concept of productivity measurement is one of work done; it refers to the results of an activity, not the activity. The effects of reengineering on productivity can be measured within the current framework for measuring productivity. The reengineered process can be measured by a work measurement scheme. The BLS Reader on Productivity (1983) describes work measurement as the analysis of the stages of activity and the requirements at each of these stages. Work measurements should be employed when exploring the options of process reengineering. Current methods of measuring productivity can then be tailored to the new process.

Whether process improvement or process reengineering, the stability of the process must be considered when using productivity data in comparative analysis. Changes in the process, technology, information quality, etc. may make current measures incomparable to past data for trend analysis. The task may be the same, but the process may have changed completely.

Curley and Henderson (1992), who proposed the assessment of IT investments at the three different levels of organization, also propose a value assessment framework that addresses business and process reengineering. This framework encompass three dimensions:

* Market measures of performance
* Measures of process change
* Technological impacts on key functionality

Combining the three levels and the three dimensions, a 3 x 3 matrix is formed for assessing the impact of a potential IT investment in nine areas. This matrix can form the basis for a subsequent productivity measurement by objectives matrix once IT investment has been made. The market measures of performance, measures of process change and technological impacts can be the productivity criteria and target goals can be established.

VI. CONCLUSION AND RECOMMENDATION

A productivity measure, in the raw sense, measures the efficiency with which input resources are used to produce outputs. In that context, the input-output methodology can be reasonable applied when outputs and input are easily identifiable and quantifiable. With the post-industrial emphasis on quality, a productivity methodology must include effectiveness and other factors that indirectly impact productivity. The productivity by objectives methodology meets these needs. This methodology is recommended for use by DOD functional managers. It offers the flexibility and global view of the organization needed to assess white collar productivity and support management decisions about process reengineering and IT investments. The main advantages of this methodology are:

* It can be used at all levels of an organization;
* The matrix can be applied to manufacturing, governmental, service, professional, technical and administrative type functions;
* It incorporates the benefits of family measures; many dimensions of performance can be tracked at the same time;
* All measures can be related to each other because the measures are normalized;

* Efficiency and effectiveness ratios can be tracked simultaneously;

* Impacts on productivity by highlighting goals.

The main disadvantages of this methodology is that the process can be confusing and not easily accepted or trusted.

These general recommendations are offered to the DOD functional manager:

* The legitimacy of the application of current methodologies depends largely on the intended use of the measure. The absolute first question a manager should ask is: If productivity is in fact what I want to measure, how will the results be used? Tailor the measure to its intended use;

* Construct a model of the process to be measured. Modelling can: help in the identification of inputs and outputs; identify external influences on the process; uncover non-value adding procedures; provide insight into possible process improvements and reengineering and potential IT investments;

* Approach productivity measurement as an evolutionary process. Start with the inputs and outputs or productivity criteria that are easily quantifiable. Develop surrogate measures for the intangibles. Add a quality dimension to the outputs. Periodically refine and revamp those measures. Productivity measures impact performance, care must be taken to ensure the measure does not induce inappropriate behavior;

* In developing labor input, often man-hours are treated as homogenous and additive. This treatment ignores the qualitative aspects of hours worked by different people. A scheme to differentiate man-hours should be developed. The rank and rating system could possibly be used to develop this scheme; and

* Activity accounting should be used when possible.

Measuring productivity is complex and expected to grow in complexity. Measurement must be used with

circumspection. Nonetheless, a well constructed productivity measure can be a catalyst for improvement and worth the undertaking.

REFERENCES

Adler, P.S., "A Plant Productivity Measure for 'High-Tech' Manufacturing, Interfaces, The Institute of Management Sciences, 1987.

Anderson, D. et al., An Introduction to Management Science, West Publishing Co., 1991.

Anthony, G. M., "IEs Measure Work, Write Standards for White Collar Workers at Financial Institution", lecture at Puget Sound Chapter of IIE, Sept 1982.

Bain, D., The Productivity Prescription: The Manager's Guide to Improving Productivity and Profits, McGraw-Hill Book Co., 1982.

Bolte, K. A., "Intel's War for White-Collar Productivity", National Productivity Review, Oregon Productivity Center, Winter 1983-1984.

Brinkerhoff, R. O., and D. E. Dressler, Productivity Measurement: A Guide for Managers and Evaluators, Sage Publications, 1990.

Business Week, "The Productivity Paradox," Special Report, June 6, 1988.

Carlson, W. M., and B. C. McNurlin, "Uncovering the Information Technology Payoffs," I/S Analyzer, 1992.

Christ, C. F. et al., Measurement in Economics, Stanford University Press, 1963.

Christopher, W. F., "How to Measure and Improve Productivity in Professional, Administrative, and Service Organizations", Commentary, Vol. 3, Number 5, 1983.

Craig, C. E. and Harris, R. C., Total Productivity Measurement at the Firm Level, Alfred P. Sloan School of Management, Massachusetts Institute of Technology, 1972.

Curley, K., and J. Henderson, "Assessing the Value of a Corporate-wide Human Resource Information System: A Case Study," Journal of Management Systems, 1992.

Denison, E., Estimates of Productivity Change by Industry: An Evaluation and an Alternative, The Brookings Institution, 1989.

Emery, J., Management Information Systems: The Critical Strategic Resource, Oxford University Press, 1987.

Fabricant, S. "Productivity Measurement and Analysis: An Overview", Measuring Productivity: Trends and Comparisons from the First International Productivity Symposium, UNIPUB, 1984.

Fabricant, S. "Problems of Productivity Measurement", Measuring Productivity: Trends and Comparisons from the First International Productivity Symposium, UNIPUB, 1984.

Felix, G. H., and J. L. Riggs, "Productivity Measurement by Objective, National Productivity Review, Oregon Productivity Center, 1983.

Forte, D., "The Challenge: Measuring Productivity in the Federal Government", Productivity and Quality Improvements in Government, Institute of Industrial Engineers, 1992.

Hammer, M., "Reengineering Work: Don't Automate, Obliterate", Harvard Business Review, President and Fellows of Harvard College, 1990.

Jablonski, M., K. Kunze, and P. F. Otto, "Hours at Work: A New Base for BLS Productivity Statistics", Monthly Labor Review, 1990.

Jones, C. guest lecture on Function Point Analysis, Naval Postgraduate School, 1993.

Keen, P., Shaping the Future: Business Design through Information Technology, Harvard Business School Press, 1991.

Miller, J. "Productivity's New Math", Brief, vol. 67, American Productivity and Quality Center, 1988.

Panko, R., "Is Office Productivity Stagnant," MIS Quarterly, June 1991.

Ruch, W. A., "Your Key to Planning for Profits", Productivity Brief, vol. 6, American Productivity Center, 1981.

Sprague, R. H. and B. C. McNurlin, Information Systems Management in Practice, Prentice Hall, 1993.

Thor, C. G., "White Collar Productivity Measurement: Ideas, Philosophies, and Practical Measurement Tools", Productivity SA, National Productivity Institute, 1985.

U.S. Department of Labor, Bureau of Labor Statistics, A BLS Reader on Productivity, Bulletin 2171, Government Printing Office, Washington D.C., 1983.

U.S. Department of Labor, Bureau of Labor Statistics, BLS Handbook of Methods, Bulletin 2414, Government Printing Office, Washington D.C., 1992.

Yan, C., Introduction to Input-Output Economics, Holt, Rinehart and Winston, 1969.

BIBLIOGRAPHY

Adler, P.S., "A Plant Productivity Measure for 'High-Tech' Manufacturing, Interfaces, The Institute of Management Sciences, 1987.

Anderson, D. et al., An Introduction to Management Science, West Publishing Co., 1991.

Anthony, G. M., "IEs Measure Work, Write Standards for White Collar Workers at Financial Institution", lecture at Puget Sound Chapter of IIE, Sept 1982.

Bain, D., The Productivity Prescription: The Manager's Guide to Improving Productivity and Profits, McGraw-Hill Book Co., 1982.

Bolte, K. A., "Intel's War for White-Collar Productivity", National Productivity Review, Oregon Productivity Center, Winter 1983-1984.

Brinkerhoff, R. O., and D. E. Dressler, Productivity Measurement: A Guide for Managers and Evaluators, Sage Publications, 1990.

Business Week, "The Productivity Paradox," Special Report, June 6, 1988.

Carlson, W. M., and B. C. McNurlin, "Uncovering the Information Technology Payoffs," I/S Analyzer, 1992.

Christ, C. F. et al., Measurement in Economics, Stanford University Press, 1963.

Christopher, W. F., "How to Measure and Improve Productivity in Professional, Administrative, and Service Organizations", Commentary, Vol. 3, Number 5, 1983.

Craig, C. E. and Harris, R. C., Total Productivity Measurement at the Firm Level, Alfred P. Sloan School of Management, Massachusetts Institute of Technology, 1972.

Curley, K., and J. Henderson, "Assessing the Value of a Corporate-wide Human Resource Information System: A Case Study," Journal of Management Systems, 1992.

Denison, E., Estimates of Productivity Change by Industry: An Evaluation and an Alternative, The Brookings Institution, 1989.

Emery, J., Management Information Systems: The Critical Strategic Resource, Oxford University Press, 1987.

Fabricant, S. "Productivity Measurement and Analysis: An Overview", Measuring Productivity: Trends and Comparisons from the First International Productivity Symposium, UNIPUB, 1984.

Fabricant, S. "Problems of Productivity Measurement", Measuring Productivity: Trends and Comparisons from the First International Productivity Symposium, UNIPUB, 1984.

Felix, G. H., and J. L. Riggs, "Productivity Measurement by Objective, National Productivity Review, Oregon Productivity Center, 1983.

Forte, D., "The Challenge: Measuring Productivity in the federal Government", Productivity and Quality Improvements in Government, Institute of Industrial Engineers, 1992.

Hammer, M., "Reengineering Work: Don't Automate, Obliterate", Harvard Business Review, President and Fellows of Harvard College, 1990.

Harvey, J., "Measuring Productivity in Professional Services", Public Productivity Review, Jossey-Bass, 1987.

Jablonski, M., K. Kunze, and P. F. Otto, "Hours at Work: A New Base for BLS Productivity Statistics", Monthly Labor Review, 1990.

Jones, C. guest lecture on Function Point Analysis, Naval Postgraduate School, 1993.

Keen, P., Shaping the Future: Business Design through Information Technology, Harvard Business School Press, 1991.

Miller, J. "Productivity's New Math", Brief, vol. 67, American Productivity and Quality Center, 1988.

Panko, R., "Is Office Productivity Stagnant," MIS Quarterly, June 1991.

Rowe, D. L., "How Westinghouse Measures White Collar Productivity, Management Review, AMACOM, 1981.

Ruch, W. A., "Your Key to Planning for Profits", Productivity Brief, vol. 6, American Productivity Center, 1981.

Sprague, R. H. and B. C. McNurlin, Information Systems Management in Practice, Prentice Hall, 1993.

Thor, C. G., "White Collar Productivity Measurement: Ideas, Philosophies, and Practical Measurement Tools", Productivity SA, National Productivity Institute, 1985.

U.S. Department of Labor, Bureau of Labor Statistics, A BLS Reader on Productivity, Bulletin 2171, Government Printing Office, Washington D.C., 1983.

U.S. Department of Labor, Bureau of Labor Statistics, BLS Handbook of Methods, Bulletin 2414, Government Printing Office, Washington D.C., 1992.

Yan, C., Introduction to Input-Output Economics, Holt, Rinehart and Winston, 1969.

APPENDIX

Sample Output Measures by Function
Federal Productivity Measurement Program

Audit of Operations
- Installation audits completed
- Pricing proposal audits
- Internal operations audited

Buildings and Grounds
- Acres of fine lawn maintained
- Average square feet cleaned
- Minor maintenance items repaired

Communications
- Messages processed
- Telegrams processed
- Telephone calls transmitted

Education and Training
- Flight training (student years)
- Student enrollment (continuing education)
- Participant training days

Electric Power Production and Distribution
- Kilowatt-hours generated
- Megawatts sold

Equipment Maintenance
- Component parts repaired (weighted composite)
- Vehicle miles driven
- Engines overhauled and repaired

Finance and Accounting
- Invoices paid
- Insurance claims processed
- Domestic payroll accounts maintained

General Support Services
- Mail items processed
- Graphic units produced
- Travellers Serviced

Information Services
- Regular reports prepared
- News releases published
- River stage forecasts made

Legal and Judicial Activities
- Cases disposed
- Settlements and decisions rendered
- Appellate decisions entered

Library Services
- Circulation items loaned
- Reference questions answered
- Periodicals and new journals routed

Loans and Grants
- Disaster loans approved
- Minority business grants issued
- Rehabilitation loan applications processed

Medical Services
- Medical care provided (weighted composite)
- Clinical visits made
- Outpatient visits conducted

Military Base Services
- Meals served
- Pieces processed (laundry)

APPENDIX (cont.)

Natural Resources & Environmental Management
- Miles of trails maintained
- Pounds of fish raised
- River basin studies completed

Personnel Investigations
- Inspections conducted
- Clearances conducted
- Position sensitivity determinations made

Personnel Management
- Retirement actions completed
- Incentive award forms completed
- Vacancies filled

Printing and Duplication
- Equivalent sheets printed
- Paper copies reproduced
- Offset printing impressions made

Procurement
- Contract actions completed
- Line items purchased
- Purchase actions processed

Records Management
- Records updated
- Archival information services provided
- Reference services completed

Regulation - Compliance and Enforcement
- Cotton samples classified
- Inspections conducted
- Cattle herds tested for brucellosis

Regulation - Rulemaking and Licensing
- Trademark applications disposed
- Permits issued or reissued
- Licenses processed

Social Services and Benefits
- Compensation claims paid
- Hospital insurance claims processed
- SSI change of address made

Specialized Manufacturing
- Munitions produced (equivalent units)
- Ton of fertilizer materials produced
- Millions of coins produced

Supply and Inventory Control
- Line items processed
- Requisitions processed
- Short tons received and shipped

Traffic Management
- Tons of cargo moved
- Personal property shipments completed

Transportation
- Fleet miles operated
- Revenue ton-miles of freight & passenger carried
- Icebreaker support days provided

INITIAL DISTRIBUTION LIST

1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22304-6145	2
2.	Superintendent Attn: Library, Code 52 Naval Postgraduate School Monterey, California 93943-5002	2
3.	Chairman of Administrative Science Department Prof. David R. Whipple, Code AS/WP Naval Postgraduate School Monterey, California 93943-5000	1
4.	Prof. William J. Haga, Code AS/HG Naval Postgraduate School Monterey, California 93943-5000	1
5.	Prof. William R. Gates Naval Postgraduate School Monterey, California 93943-5000	1
6.	LT Maxie Y. Davis 472 Wellington Street Mobile, Alabama 36617	2